Method of testing bonded connections, and a wire bonder

DESCRIPTION

The invention relates to a method of testing bonded connections and to a wire bonder equipped with a corresponding, integrated testing arrangement.

Wire bonding is a method in which electrical connections of semiconductor components are produced by means of fine metal wires. With wire-bond connections, for example, the contact surfaces of discrete components can be electrically connected to one another, or integrated circuits to contact surfaces on the associated housing or, in the case of hybrid circuits, inserted monolithic elements can be electrically connected to the thick-film circuitry into which they have been inserted.

In the course of the development of technology for connecting semiconductor components and circuits, various bonding methods have been invented and a large number of bonding machines suitable for this purpose have been proposed. The most commonly used wire-bonding methods are ultrasound (U/S) bonding, thermal-compression (T/C) bonding, and thermosound (T/S) bonding. Wire bonders to implement these methods guide a bonding wire to the point (bond pad) provided for the purpose of creating the bonded connection, and then by means of a bonding tool, for instance in the form of a capillary, wedge or nailhead, the wire is deformed and fixed in place by application of a compressive force and the supplementary action of oscillatory and/or thermal energy. In this process, a kind

of welded connection is formed between the bonding wire and the bond pad.

The quality of the bonded connection is crucial for the functionality and reliability of the electronic components constructed by employing the bonding method. Therefore it is desirable, if not indispensable, for the parameters of the bonding process to be monitored while the process is under way, as well as for the quality of the finished bonded connection to be tested. Various solutions to the problem of monitoring and regulating essential parameters of the ongoing bonding process – in particular the bonding force and where appropriate also the ultrasound amplitude or energy – have been proposed.

In the patent US 4,854,494 a wire bonder is described that comprises means for monitoring several bonding parameters, especially the bonding force and ultrasound amplitude. This wire bonder has a tool holder with a weakened section, where bowing can occur when the tool is used to press the bonding wire onto the bond pad. By way of a strain gauge disposed in this weakened section, the momentary bonding force is detected and can be kept at a predetermined set point by way of a downstream regulation system.

The patent US 5,230,458 likewise describes a bonding head with a force sensor that measures the compressive force exerted by the bonding tool and signals it to a real-time control circuit. The latter sends an adjustment signal to an actuator that causes a movement in the Z direction, to adjust the bonding force. The bonding machine described here is an ultrasonic bonder of the capillary type, in which the ultrasound transmitter, with capillary attached to serve as bonding tool, is mounted on a carrier frame. This frame also carries an extension arm to guide the bonding wire, which is disposed above another extension arm bearing the ultrasound transmitter.

In the applicant's patent GB 2 270 868 A a wire-bonding method and system of a different type is described, namely the ultrasonic (U/S) wedge bonder, in which likewise provision is made for the detection and continuous regulation of bonding force and ultrasonic energy. For this purpose, the deformation of the bonding wire is monitored.

The applicant's patent EP 0 857 535 A1 describes a bonding head with two extension arms, the first of which (tool holder) carries the bonding tool while the second (wire-clamp holder), disposed above the first, carries a wire clamp to grasp a bonding wire and fix it in position. Here, again, the bonder is of the U/S wedge type. The bonding force is adjusted by the action of a linear motor in combination with a pretensioning spring, in response to the signal of a piezo detector disposed at the end of the tool holder.

Moreover, a known method of testing bonded connections is to exert a tensile force with a predetermined value on the attached bonding wire. If the bonded connection withstands this tensile force, it is judged to be qualitatively perfect. This test is carried out as a procedure following the manufacturing process.

It is the objective of the invention to disclose a method of testing bonded connections that is directly integrated into the manufacturing process, as well as a wire bonder suitable for implementing this method, which enables real-time quality control and the immediate execution of quality-ensuring adjustment procedures while the bonding process is still under way.

This objective is achieved with respect to the method by a testing procedure with the characteristics given in Claim 1, and with respect to the apparatus by a wire bonder with the characteristics given in Claim 4.

The invention includes the essential idea of exposing a bonded connection to a tensile force immediately after it has been created, and of detecting its response. It further includes the idea that for this purpose the bonding tool and a wire clamp to grip the bonding wire should be moved in a suitable sequence of steps, in combination with a step in which the tensile force is measured, and the idea of disclosing a corresponding arrangement of a tool holder and a wire-clamp holder in combination with a control and evaluation means adapted thereto. An essential characteristic of the execution of the procedure is that the bonding wire is firmly gripped and pulled as soon as the bonded connection has been created (but after the contact between the bonded connection and the bonding tool has been broken), during simultaneous measurement of the tensile force.

In particular, the bonding head or the wire clamp is raised through a second distance calculated in dependence on the structural features, in such a way that during the raising process a predetermined or programmed tensile force is generated and the intactness of the bonded connection is monitored. The latter is achieved by observing the time course of the tensile force acting on the wire clamp during raising. If the bonded connection were to break while the test force is being applied, the result would be a sudden decrease in the measured force, and even slighter anomalies in the time course of the measured tensile force can indicate deficiencies in the quality of the bonded connection and – as the result of an appropriate evaluation – provide a reason to modify the process parameters.

A testing arrangement suitable for implementing the proposed solution comprises, as an essential element, the wire-clamp holder (which is known per se) provided with an associated force-measuring element and a control device to control the movement pattern sketched out above, and represents an integrated component of an improved wire bonder.

In advantageous embodiments of this testing arrangement, the wire-clamp holder is seated on the bonding head in such a way that it can be elastically rotated or linearly displaced against the action of a pretensioning element. A force-measuring element, in particular a strain gauge, is associated with the holder, which also comprises a weakened section in which the tensile force delivered by the drive mechanism causes an elastic deformation (bending, twisting or stretching) of the holder. In particular, the force-measuring element (specifically, the strain gauge) is also disposed there, so as to obtain a force-measurement signal that can be unambiguously evaluated.

So that the testing arrangement can be sensibly integrated into a modern wire bonding machine, the above-mentioned control device is designed as a program control system and permits the testing program to be automatically executed at all or selected bonded connections that are created with the wire bonder.

Other advantages and useful features of the invention will be apparent from the subordinate claims and from the following description of a preferred exemplary embodiment with reference to the figure. This shows, in a schematic drawing, a testing arrangement 1 with essential components of the bonding head 3 of an ultrasonic wire bonder constructed in accordance with the invention. The elementary diagram refers to a bonding head of the kind described in the patent EP 0 857 535 A1, the structural details of which are not shown here. In the nature of a synoptic representation, function blocks are added with evaluation and control functions and symbols for the essential procedural steps.

The bonding head 3 comprises a transducer holder 5, in which is mounted an extension arm bearing an ultrasound transducer 7 and, attached thereto, a bonding tool 9 (e.g., of the capillary or wedge type), and a wire-clamp holder 11, which bears a wire clamp 13 for the controlled fixation of a bonding wire 15. On a

substrate 17 the bonding head produces, in a manner known per se, a bonded connection 19, the stability of which is to be tested by means of the testing arrangement 1.

The wire-clamp holder 11, in a middle region along its length, has a leaf-spring section 21 as a preferential bending section, in which is attached a strain gauge 23 or similar force sensor that responds to bending deformation.

A drive mechanism 25 (here shown for simplicity as a single block) of the bonding head 3 controls the bonding head or, as separately movable components, the tool holder 5 and the associated extension arm with the transducer 7 as well as the wire-clamp holder 11 and the wire clamp 13, not only in order to move them in the manner known per se to generate the bonded connection 19, but in addition according to a testing program of the kind described above, which is stored in a program memory unit 27. As a result, in particular the following sequence is controlled: a first step S1 in which the bonding tool 9 is lifted slightly away from the bonded connection 19 that has been produced, a second step S2 in which the bonding wire 15 is firmly clamped, a step S3 in which the wire clamp 13 is raised together with the clamped bonding wire 15, and a step S4 in which an initial value signalled by the strain gauge 23 during lifting is detected.

The strain gauge 23 is connected to a tensile-force evaluation unit 29, and its output signal is there evaluated according to a pre-specified algorithm – for example, incorporating a threshold discrimination with respect to a minimal tensile-force value. On the output side the tensile-force evaluation unit 29 is connected to a bonding-parameter control unit 31, in which the result of the evaluation is converted as appropriate into pre-determined changes of the bonding parameters, to ensure the quality of the bonded connection 19.

The embodiment of the invention is not restricted to the example described above, but is also possible in a large number of modifications that are within the competence of a person skilled in the art.

List of reference numerals

1	Testing arrangement
3	Bonding head
5	Transducer holder
7	Transducer
9	Bonding tool
11	Wire-clamp holder
13	Wire clamp
15	Bonding wire
17	Substrate
19	Bonded connection
21	Leaf-spring section
23	Strain gauge
25	Drive mechanism
27	Program memory unit
29	Tensile-force evaluation unit
31	Bonding-parameter control unit